

Comparing the Foraging Efficiency of Beaked Whales On and Off Naval Ranges

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LONG-TERM GOALS

The long-term goal of this project is to contribute to an overall understanding of the influence threat-induced disturbance has on the population health of beaked whales on and off naval ranges. By gathering and analyzing data on foraging performance and efficiency this project will provide detailed energetics data for modeling approaches assessing population level effects.

OBJECTIVES

The overall objective of this project is to improve the understanding of sonar disturbance on Blainville's beaked whales (*Mesoplodon densirostris*) inhabiting the Atlantic Undersea Test and Evaluation Center (AUTEK) range in the Tongue of the Ocean (TOTO), by deploying DTAGs and comparing foraging efficiency and performance.

The primary objectives of this research are to:

- DTAG Blainville's beaked whales on the AUTEK range and collect detailed data on foraging and locomotion.
- Deploy DTAGs at an alternative location, South Abaco island (SA), where naval sonar is not regularly used.
- Opportunistically DTAG Blainville's beaked whales in known displacement habitats within TOTO.
- Compare DTAG foraging data from all three areas and across years to investigate whether foraging behavior and efficiency shows variation.
- Quantify the diving behavior of Blainville's beaked whales recorded at each site.
- Quantify the prey capture and relative foraging costs associated with feeding at each site.
- Make experimental data available to other stakeholders to inform energetics models.

Specific to the 2015 field effort, the primary objective was to:

- Deploy DTAGs at South Abaco island (SA), where naval sonar is not regularly used.
- Quantify the diving behavior of Blainville's beaked whales recorded at the SA site.

APPROACH

The University of St Andrews was the prime grantee for this project. The PI, Peter Tyack, is the technical representative responsible for overseeing the safe and successful conduct of the cruise. Leigh Hickmott, also supported directly through the University of St Andrews, acted as the cruise leader and was responsible for all pre-cruise logistic planning and the completion of the field efforts. Woods Hole Oceanographic Institution (WHOI) was subcontracted to provide DTAGs and associated supplies. The Bahamas Marine Mammal Survey Organisation (BMMRO) was subcontracted to provide a research vessel, accommodation, logistic support in The Bahamas and personnel. In addition, BMMRO provided detailed life history data for the encountered and tagged Blainville's beaked whales.

Our group has conducted three previous DTAG cruises for Blainville's beaked whales in The Bahamas, in 2006, 07 and 08. To date, 8 Blainville's beaked whales have been Dtagged, resulting in 95.4 hours of tag data. These 8 animals were all tagged in the Tongue of the Ocean, off the eastern side of Andros Island, and are members of a sub-population of Blainville's beaked whales that inhabit the waters of the AUTEK range and adjacent areas.

Our 2015 field efforts were focused on collecting DTAG data at the SA field site. SA lies only 170 km north of AUTEK yet is an area where whales are not regularly exposed to sonar. Longitudinal beaked whale population studies have taken place at both study sites (AUTEK, since 2005 and SA, since 1997). The detailed nature of studies on exposed and unexposed sub-populations, combined with the small geographic distance between them, presents a data rich and unique situation to investigate foraging differences. By comparing in detail the foraging choices and behavior made at 1) AUTEK, 2) SA and 3) displacement habitats, this study will, for the first time, provide a means to examine variation in foraging efficiency and energetic costs resulting from sonar disturbance.

The month of June was chosen for the field effort to take place, based on both historical Blainville's beaked whale sighting and weather data to provide the highest number of tagging opportunities.

A 7 m rigid hulled inflatable boat (RHIB) was employed as the principle survey and tagging vessel, suiting the experimental requirements perfectly. The RHIB comfortably accommodated the 4 personnel and associated tagging and radio tracking equipment. Importantly, with its new 200Hp 4-stroke Yamaha engine the RHIB was the ideal size to survey for animals and subsequently make quiet and successful tagging approaches. The RHIB remained at sea during daylight hours, returning to shore at night.

Whale tag - The DTAG version 3 is a miniature sound and orientation recording tag developed at WHOI. The tag contains a VHF transmitter used to track the tagged whale during deployment and to retrieve the tag after release. DTAGs record stereo sound at the whale as well as depth, 3-dimensional acceleration, and 3-dimensional magnetometer information. DTAG audio was sampled at 192 kHz and other sensors at 50 Hz, allowing for a fine reconstruction of whale behavior. The tag is attached to the

whale with suction cups using a hand held carbon fiber pole that is 7 m long. The hand held pole technique for deployment of DTAGs has been used in many previous field trials.

Tracking and data collection - To visually search for animals and to observe the behavior of the animals during tagging and tracking, observers scanned with naked eye and 10 X 42 binoculars. VHF radio tracking of the DTAG was conducted using handheld yagi antennas and R1000 receivers. During nighttime tracking from the BMMRO research station, a pole mounted yagi antenna was monitored from the roof of the research station, giving a reception range of ~22 km.

WORK COMPLETED

A 16 day field effort took place in June 2015. The BMMRO research station located in Sandy Point, Abaco, was used as the base for the effort (Fig. 1). On days where sea conditions were favorable for detecting and tagging beaked whales, the RHIB was launched at first light to begin searching for whales. The RHIB and new engine performed as predicted, being a stable survey and tagging platform. The small well trained crew was able to detect, tag and track beaked whale groups over long experimental periods. The crew smoothly transitioned from visual to acoustic tracking and visa versa as whales undertook foraging dives or as the sea state changed and altered the likelihood of visual detection. Nighttime tracking from the research station proved effective and safe (removing the need to be at sea at night in a small vessel). Searching for and recovering tags post-deployment worked well on the RHIB. Tags could be detected from the deck of the RHIB at ~10 km and working in a small fast vessel allowed for efficient and fast tag recovery.

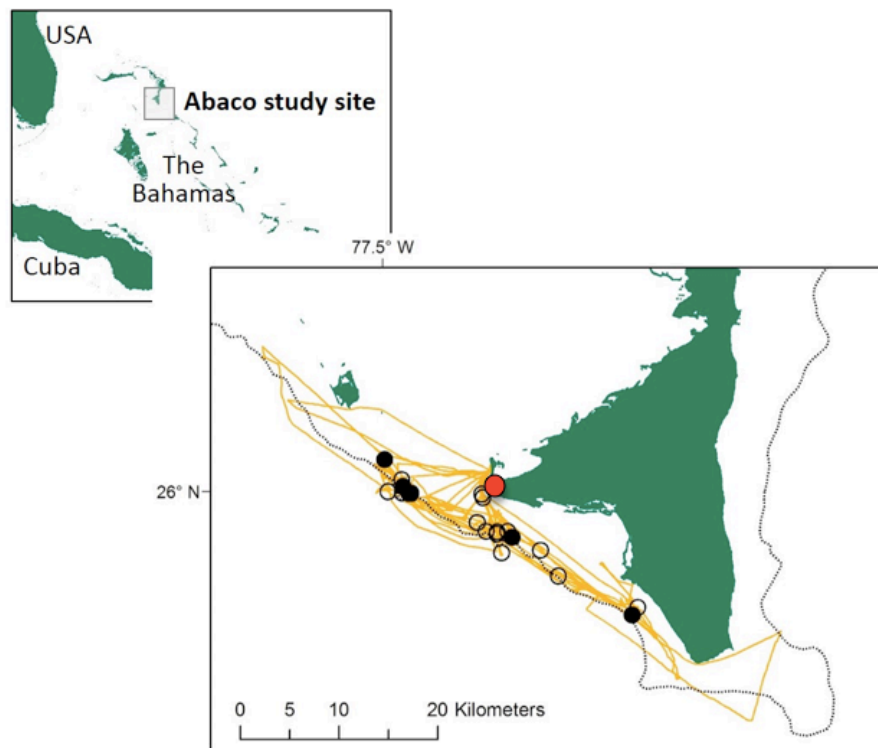


Figure 1. A map depicting the location of the SA study site, with the BMMRO research station (red circle). Vessel effort/tracks are depicted by the orange lines. Blainville's beaked whale (black circles) and all other species (open circles) encounter locations are shown, along with the 1000 m isobath (dashed line).

Three DTAG3 tags were supplied by WHOI and prepared each day for deployment. During the field effort, two tags developed electronic faults after being deployed on whales and subsequently could not be redeployed. This reduction in available hardware to one functioning tag, limited the team's ability to collect data during the latter part of the field effort.

RESULTS

Effort – During 8 workable vessel days, 678 km of 'at sea' effort were completed over a period of 70.5 hours (Fig. 1). 20 cetacean sightings, comprising of 4 different species were recorded (Table 1). Across all species, 71 individual animals were documented and the time spent during animal encounters totaled 35.8 hours (Table 2).

Table 1. Table of species recorded, with the number of encounters per species, mean group sizes and ranges.

Species	No. of Encounters	Mean Group Size (Range)
Blainville's beaked whale – <i>Mesoplodon densirostris</i>	5	4.2 (1-8)
Bottlenose dolphin – <i>Tursiops truncatus</i>	2	4.5 (3-6)
Dwarf sperm whale – <i>Kogia sima</i>	10	2.1 (1-7)
Sperm whale – <i>Physeter macrocephalus</i>	1	12 (12)
Unknown Kogia – <i>Kogia spp.</i>	1	4 (4)
Unknown Ziphiid	1	4 (4)

Blainville's beaked whale sightings – Groups of Blainville's beaked whales, ranging in size from 1 to 8, were observed on 5 occasions for a total of 27.7 hours. 639 photo-ID images were collected of 13 different individuals. 12 of the identified whales have been previously observed and photographically catalogued by BMMRO.

DTAG effort – Six tagging attempts were made on six different individual Blainville's beaked whales, with five successful deployments. Two adult males, one adult female, one sub-adult male and one sub-adult female were tagged (Fig. 2). All tagged animals had been previously encountered by BMMRO and were individuals with known life histories (Table 3). Dive profiles were generated from the tag pressure sensor data and are similar to previously collected profiles described from the AUTECH range (Tyack *et al.* 2011) (Fig. 3).

In total 58.8 hours of DTAG data were collected, with deployments lasting a maximum of 17.9 hours (Table 4). 29 foraging dives were recorded, with a mean inter-deep dive interval of 1.3 hours (S.D. 0.6). Foraging dives had a mean duration of 48.3 minutes (S.D. 5) and mean maximum depth of 1106 m (S.D. 151) (Table 4). During foraging dives, echolocation clicks and buzzes (rapid click sequences associated with prey capture attempts), described by Johnson *et al.* (2004), were recorded. Foraging periods, defined by the regular production of echolocation clicks during deep dives, had a mean duration of 28.5 minutes (S.D. 6.3). During these foraging bouts, 1536 buzzes were recorded and animals produced an average of 53.3 buzzes (S.D. 19.4) (range 21 – 93) per dive. Buzzes were produced between depths of 400 and 1450m, with the highest frequency being recorded between 800 and 1000 m (mean buzz depth = 955.9 m (S.D. 156.8))(Fig. 4).

Table 2. Species sighted during 8 vessel days, with group sizes, locations and encounter durations.

Date	Species	Group Size	Encounter Start Time	Latitude	Longitude	Elapsed Time (min)
05-Jun-15	Blainville's beaked whale	7	12:55:00	25.9985	-77.4763	350
06-Jun-15	Dwarf sperm whale	2	15:37:50	25.9636	-77.3959	13
06-Jun-15	Unknown Ziphiid species	4	15:50:51	25.9444	-77.3919	61
07-Jun-15	Blainville's beaked whale	4	12:59:00	25.8883	-77.2732	233
07-Jun-15	Dwarf sperm whale	3	16:58:30	25.8952	-77.2679	2
07-Jun-15	Bottlenose dolphin - coastal	6	07:04:05	25.9979	-77.41	1
07-Jun-15	Dwarf sperm whale	1	07:42:00	25.9638	-77.4061	6
07-Jun-15	Dwarf sperm whale	1	08:31:00	25.9985	-77.4743	1
07-Jun-15	Dwarf sperm whale	1	10:51:00	25.9618	-77.3962	1
07-Jun-15	Dwarf sperm whale	1	11:27:00	25.9235	-77.3402	3
08-Jun-15	Dwarf sperm whale	7	09:50:00	25.9641	-77.3863	13
08-Jun-15	Sperm whale	12	10:39:00	25.9719	-77.4141	377
08-Jun-15	Dwarf sperm whale	1	14:41:00	25.9468	-77.3564	5
08-Jun-15	Bottlenose dolphin - coastal	3	06:41:00	25.9949	-77.4088	1
08-Jun-15	Dwarf sperm whale	1	15:57:00	25.9988	-77.4823	1
09-Jun-15	Blainville's beaked whale	1	09:51:00	26.0289	-77.4981	82
09-Jun-15	Blainville's beaked whale	1	11:40:00	25.9588	-77.3825	349
10-Jun-15	Unknown Kogia species	4	14:33:00	26.0002	-77.495	1
10-Jun-15	Dwarf sperm whale	3	15:06:00	26.0107	-77.4825	1
11-Jun-15	Blainville's beaked whale	8	08:39:37	26.0046	-77.4814	647

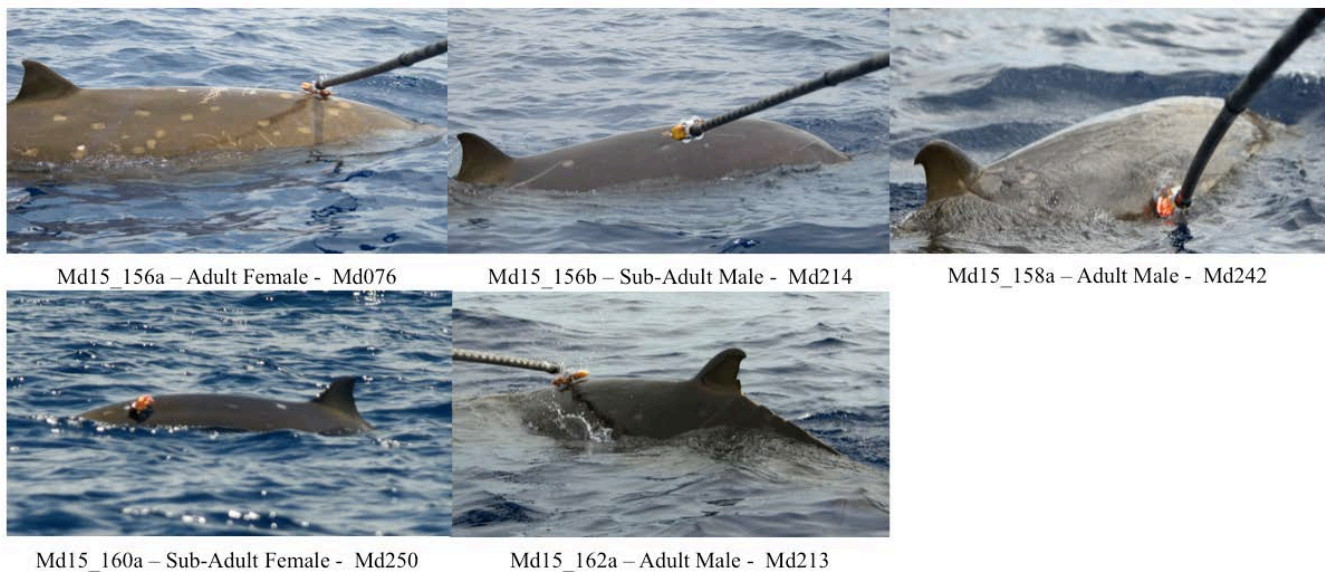


Figure 2. Images of the 5 tagged Blainville's beaked whales, with their tagging ID number, age class and BMMRO photo-identification number.

Table 3. Table of sighting histories, age classes and biopsy status of the five tagged Blainville's beaked whales.

Date	DTAG Deployment ID	Whale ID	Historical No. of Sightings	No. of Years Seen	Age-sex class (when tagged)	Comments
05-Jun-15	md15_156a	Md076	41	11	AF	Has had at least 4 calves
05-Jun-15	md15_156b	Md214	4	2	SM	Born in 2006, calf of Md076
07-Jun-15	md15_158a	Md242	6	4	AM	Biopsied in 2012
09-Jun-15	md15_160a	Md250	9	4	SF	Born in 2010, calf of Md134; biopsied in 2013
11-Jun-15	md15_162a	Md213	4	4	AM	Biopsied in 2013

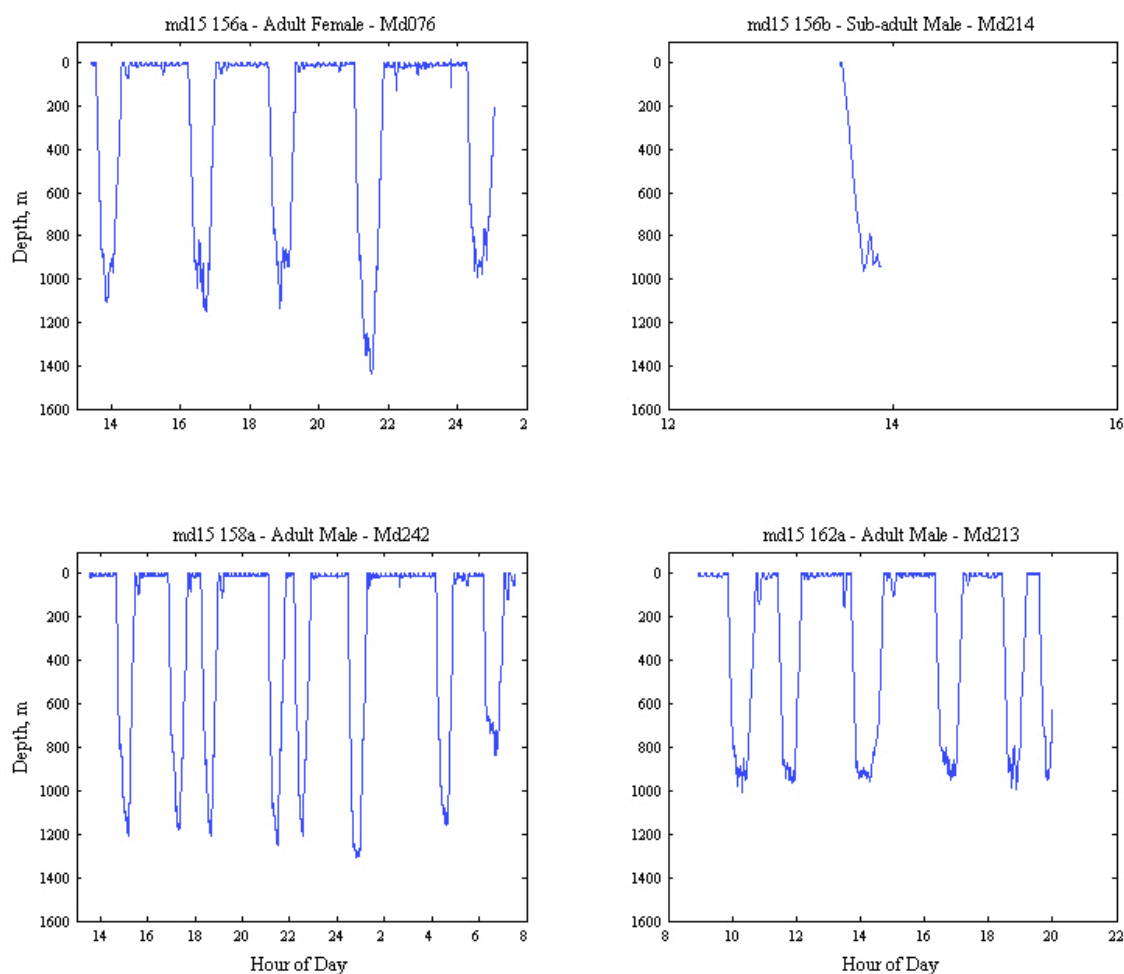


Figure 3. Dive profiles of four of the tagged Blainville's beaked whales. A pressure sensor calibration issue for the deployment md15_160a, has currently prevented the plotting of this animals dive profile.

Table 4. Deployment, foraging dive and prey capture attempt summaries for the five tagged Blainville's beaked whales. N.B. with the exception of 'On-Animal Tag Time' and 'No. Foraging Dives' all values are means with standard deviations in parentheses. * Due to the DTAG detaching during the foraging dive, these values represent the data collected and not the full foraging record for that dive. ** Due to the pressure calibration issue affecting the dataset md15_160a, depth related data are not currently available.

Dataset	On-Animal Tag Time (hr)	No. Foraging Dives	Dive Duration (min)	Max. Dive Depth (m)	Foraging Duration (min)	No. Buzzes per Dive	Mean Buzz Depth (m)
md15_156a	11.6	5	48.7 (2.7)	1163.4 (166)	34.2 (4.4)	78.6 (18.4)	983.5 (160.9)
md15_156b	0.4	1	20.5*	960.5	15.5*	43*	785 (193.5)
md15_158a	17.9	8	47.6 (3.2)	1170.5 (141.6)	30.4 (3.2)	39.4 (8.2)	1015.3 (186.3)
md15_160a	17.8	9	46.4 (5.2)	**	23 (4)	45 (16.2)	**
md15_162a	11.1	6	52.4 (6.8)	971.5 (24.1)	29.6 (7.6)	63.2 (7.4)	897.3 (54.3)

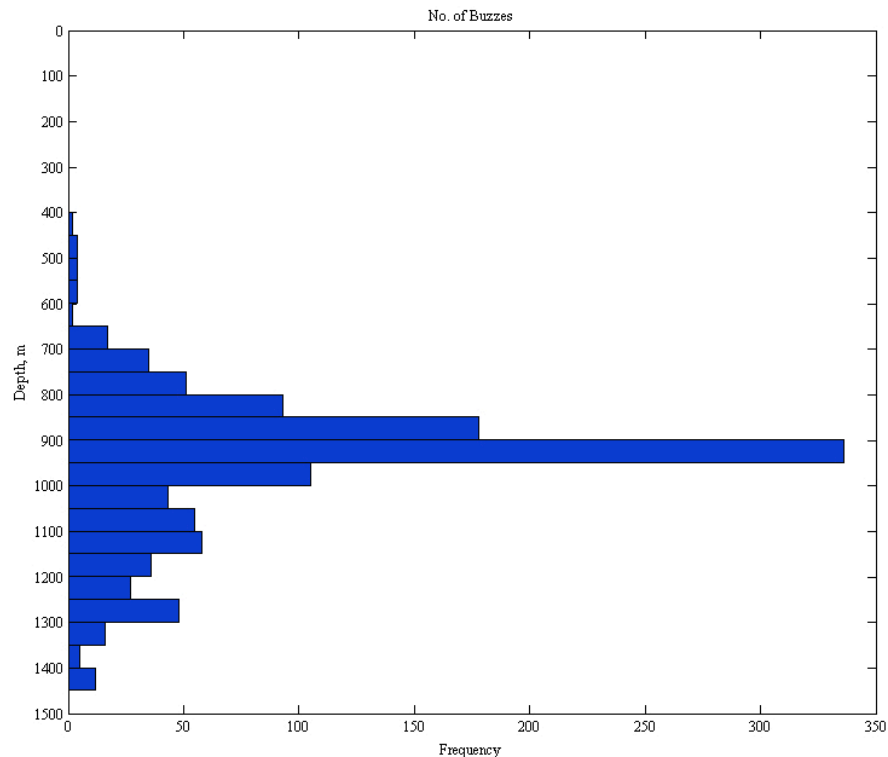


Figure 4. Frequency of foraging buzzes occurring in 50 m depth bins (n = 1131). N.B. due to the pressure calibration issue affecting the dataset md15_160a, buzz depth related data are not currently available for this animal.

Social calls – Calls considered to have a social context have been described for Blainville’s beaked whales (Aguilar de Soto *et al.* 2012; Dunn *et al.* 2013). Preliminary auditing of the acoustic recordings from the DTAG’s have found social calls similar to the rasps and whistles described by Aguilar de Soto *et al.* (2012) in two of the DTAG records (md15_158a and md15_160a). These datasets will be further analyzed to catalogue and characterize the recorded calls.

Results presented here are considered ‘quick look’ summaries of the diving and foraging behavior recorded by the DTAGs during the 5 deployments. Over the course of this three year project, these datasets will be analyzed in detail to achieve the primary objectives of this project.

IMPACT/APPLICATIONS

The small vessel, small expert team approach employed in this study was proven to be highly effective and successful. The five DTAG datasets collected during the 16 day effort are hugely valuable, as they provide the first fine-scale foraging data for Blainville’s beaked whales in The Bahamas at a site other than the AUTECH range. Direct comparisons of diving and feeding behavior between the two sites can now be made and the data used to estimate non-stranding effects of sonar in terms of energetics of foraging. Behavioral foraging and energetics data will feed directly into PCAD and PCoD frameworks, enriching the data pool used to develop statistical tools. Importantly, results generated by this project will provide relevant information to all naval operating areas and stakeholders concerned about the disturbance effects of sonar.

RELATED PROJECTS

This project is directly relevant to ONR’s mission, as it will significantly enhance environmental analysis on the effects of sonar on beaked whale populations that inhabit naval ranges. This project is synergistic with BRS, SOCAL and 3S studies, which also collect DTAG data on the foraging behavior of disturbed beaked whales. As stakeholders in these studies, the PIs of this project aim to share acquired knowledge, expertise and research developments with the BRS community. Passive acoustic monitoring collected by the M3R program during the project will add value to the MMB’s monitoring and detection area of interest with direct links to LATTE – Linking Acoustic Tests and Tagging Using Statistical Estimation, Mocha – Multi-study Ocean acoustics Human effects Analysis and DECAF – Density Estimation for Cetaceans from passive Acoustic Fixed sensors. Funding awarded to the M3R program for this study, will allow the M3R team to continue monitoring the effects of range use on marine mammals and continue to enhance their tools while supporting tagging efforts at AUTECH. Dialogues have been initiated with three other research teams to collaborate specifically on beaked whale studies in TOTO and SA. By establishing working partnerships and data collaborations, we aim to enhance the effectiveness and maximize the research output of this and the companion projects. These studies are:

Linking deep-water prey fields with odontocete population structure and behavior.

This project aims to deploy a deep-water, autonomous underwater vehicle (AUV) equipped with two split-beam echosounders to assess beaked whale prey fields in TOTO and SA. The project will sample and compare prey resources in the same areas where DTAGs will and have been deployed: 1) on the AUTECH weapons range, 2) at an undisturbed site (SA) and 3) in historic displacement areas. This is a collaborative project between K. Benoit-Bird (College of Earth, Ocean, and Atmospheric Sciences (CEOAS)), M. Moline (University of Delaware) and B. Southall (Southall Environmental Associates, Inc.).

Monitoring beaked whale movements during the Submarine Commanders Course using satellite telemetry.

The detailed foraging and energetics data generated by this DTAG project will contribute directly to the intrinsically linked satellite tag project. Satellite telemetry is being used in this project to monitor the movements and diving behavior of beaked whales and other odontocete cetacean species on the AUTECH range before, during, and after sonar exercises in which multiple ships are using tactical sonars. This is a collaborative project between BMMRO, Southwest Fisheries Science Center (SWFSC) and NUWC (David Moretti).

Beaked whale group deep dive behavior from passive acoustic monitoring.

Using a combination of DTAG and passive acoustic monitoring data, the manner in which groups of *M. densirostris* dive, forage and utilize habitats and prey patches will be assessed. Data collected using the two methods will be compared to ground truth findings from each approach. This is a collaborative project between NUWC (J. Shaffer and P. Baggenstoss), the Centre for Research into Ecological and Environmental Modeling (CREEM) (T. Marques and L. Thomas) and BMMRO.

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